

Amendments to the Specification:

Please replace the existing specification with the Substitute Specification attached hereto in the Appendix to this Amendment. No new matter is presented in the Substitute Specification. A marked-up version of the original specification, showing the changes presented in the Substitute Specification, is also included in the Appendix.

SUBSTITUTE SPECIFICATION

- 1 -

NSK2356US

CROSS JOINT

This application claims the benefit of Japanese
5 Patent Applications No. 2000-371934, 2001-219935,
2001-313941 and 2001-313945 which are hereby
incorporated by reference.

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GROUP 3600

BACKGROUND OF THE INVENTION

10 Field of the Invention

The present invention relates to a cross joint
used for a steering apparatus for, e.g., a vehicle.

Related Background Art

15 In the steering apparatus for the vehicle, a
cross joint constructed of a pair of yokes and a
cross-shaped spider and serving to propagate a torque
in a way that rotates a predetermined bending angle,
is interposed between, for instance, an upper shaft
and a lower shaft of a steering shaft.

20 According to a cross joint disclosed in, e.g.,
Japanese Patent Application Laid-Open No.2000-170786,
a shaft member of the spider is fitted into a bearing
hole of a yoke through a needle bearing, such that
said shaft member is capable of oscillating. A
25 spherical protrusion formed on an axial core of an
inner surface of a cup of the needle bearing is
fitted into and kept in contact, by pressure, with a

conical hole formed in the axial core of the spider shaft.

With this configuration, even when vibrations are propagated from wheels, a minute gap between the spider shaft and the needle bearing is kept uniform,
5 thereby preventing an emission of noises due to an interference between the spider shaft and the needle bearing.

According to the structure disclosed in Patent
10 Application Laid-Open No.2000-170786, however, if a dimensional accuracy of each component is low, when the cross joint is assembled to the yokes, it is difficult to bring the spherical protrusion provided on the inner surface of the cup of the needle bearing
15 into contact with the conical hole of the spider shaft with a proper pre-load. As a result, a minute gap between the spider shaft and the needle bearing can not be kept uniform, resulting in an emission of noises due to an interference therebetween.

20 On the other hand, if the dimensional accuracy of each component is enhanced, though capable of preventing the emission of noises, a rise in manufacturing cost is brought about as a negative aspect.

25 Further, when a steering shaft of the vehicle is steered, a steering wheel is rotated, with the result that the spider shaft is oscillated. An angle

of this oscillation is determined by a joint fitting angle in the vehicle and is on the order of ± 30 degrees in the case of an ordinary car. The rollers of the needle bearing smoothly rotate owing to the oscillations of the spider shaft.

According to Japanese Patent Application Laid-Open No.2000-170786, however, the axial core of the roller is not parallel but inclined to the axis of the spider shaft in many cases, and the roller, with its rotation, moves in the axial direction within the cup of the needle bearing. With the movement of the roller in the axial direction, the roller comes into contact with the cup wall, and sliding contact occurs between the roller and the cup wall. As a result, a bending torque of the steering shaft increases, and a smooth feeling of steering can not be obtained.

SUMMARY OF THE INVENTION

It is a first object of the present invention, which was devised under such circumstances, to provide a cross joint capable of reliably preventing an emission of noises due to an interference between a spider shaft and a rolling bearing without causing any rise in manufacturing cost.

It is a second object of the present invention to provide a cross joint capable of reliably preventing the emission of noises due to the

interference between the spider shaft and the rolling bearing and obtaining a smooth feeling by educing a bending torque of a steering shaft without bringing about any rise in manufacturing cost.

5 To accomplish the above objects, according to one aspect of the present invention, a cross joint comprises yokes each formed with a bearing hole, and a spider shaft rotatably fitted into the bearing hole through a rolling bearing. The spider shaft is
10 formed with a contact portion with the rolling bearing, the contact portion having its outside diameter larger than an outside diameter of the spider shaft.

 In the cross joint according to the present
15 invention, preferably, an axial core side end surface of the contact portion is formed with a bottomed hole. Thus, according to the present invention, the contact portion of the spider shaft is set larger than that of the central portion thereof, and hence the fitting
20 between this contact portion and the rolling bearing can be set to have an interference (or a minute gap). Accordingly, even when vibrations are propagated from the wheels, the noises emitted due to the
 interference between the spider shaft and the rolling
25 bearing can be reliably prevented by keeping uniform the minute gap between the central portion of the spider shaft and the rolling bearing.

On the other hand, the contact portion of the spider shaft has the bottomed hole at a central portion of the spider shaft end and is, in this case, formed in a comparatively thin ring shape. Hence, the contact portion has a comparatively small rigidity in its radial direction and, even when the fitting between the contact portion and the rolling bearing is set to have the interference, causes neither a large contact surface pressure nor a problem in terms of durability. Further, similarly, when assembling the cross joint to the yoke, a load for inserting (press-fitting) the rolling bearing (needle bearing) is relatively small, and there is no real difficulty with the assembly process. Moreover, there is no necessity of enhancing or improving a dimensional accuracy of each component, and the contact portion of the spider shaft is expanded in its diameter and is formed merely with the bottomed hole. This configuration does not bring about a rise in the manufacturing cost.

Moreover, the contact portion of the spider shaft is formed in a comparatively thin ring shape. Therefore, if a large load is propagated, the contact portion becomes flexural, however, the central portion of the spider shaft receives a large proportion of the load. Hence, there does not arise any significant problem in terms of strength.

Further, in the cross joint according to the present invention, an extreme-pressure additive may be added to a lubricating agent filling an interior of the needle bearing.

5 According to another aspect of the present invention, a cross joint comprises yokes each formed with a bearing hole, and a spider shaft fitted into the bearing hole through a needle bearing in a manner such that the shaft is capable of oscillating
10 movement. The needle bearing is interference-fitted to the spider shaft, and rollers provided in a bearing cup of the needle bearing, and are so structured as to be movable 0.6 mm or larger in the axial direction.

15 Thus, according to the present invention, the needle bearing and the spider shaft are interference-fitted to each other, and it is therefore feasible to reliably prevent the emission of noises due to the interference between the spider shaft and the needle
20 bearing without bringing about any rise in manufacturing cost.

 In addition, the rollers in the bearing cup of the needle bearing are so structured as to be movable 0.6 mm or larger in the axial direction. Hence, even
25 if the rollers rotate and move in the axial direction within the cup when the spider shaft is oscillated, the rollers do not come into contact with the cup

wall, and no sliding contact between the rollers and the cup wall is experienced. Accordingly, it is possible to obtain the smooth feeling of steering by reducing the bending torque of the steering shaft.

5

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side view including a partially cut-off section, showing a cross joint in a first embodiment of the present invention;

10 FIG. 2 is a sectional view of the cross joint shown in FIG. 1;

FIG. 3 is a sectional view of a cross joint shown in a second embodiment of the present invention;

15 FIG. 4 is a sectional view of a cross joint shown in a third embodiment of the present invention;

FIG. 5 is a sectional view of a cross joint shown in a fourth embodiment of the present invention;

20 FIG. 6 is a sectional view of a cross joint shown in a fifth embodiment of the present invention;

FIG. 7 is a sectional view of a cross joint shown in a sixth embodiment of the present invention;

25 FIG. 8 is a sectional view (taken in the direction of a vertical axis of the center of the joint in FIG. 1) of a cross joint shown in a seventh embodiment of the present invention;

FIG. 9 is a sectional view of a cross joint shown in an eighth embodiment of the present invention;

FIG. 10A is a side view including a partially cut-off section, showing a cross joint shown in a ninth embodiment of the present invention;

FIG. 10B is a sectional view of the cross joint shown in FIG. 10A;

FIG. 11 is a sectional view of a cross joint shown in a tenth embodiment of the present invention;

FIG. 12 is a sectional view of a cross joint shown in an eleventh embodiment of the present invention;

FIGS. 13A and 13B are sectional views each showing a cross joint shown in a twelfth embodiment of the present invention;

FIG. 14A is a sectional view of a cross joint in a thirteenth embodiment of the present invention; and

FIG. 14B is a sectional view of a cross joint in a fourteenth embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[First Embodiment]

FIG. 1 is a side view including a partially cut-off section, showing a cross joint in a first embodiment of the present invention. FIG. 2 is a

sectional view of the cross joint illustrated in FIG. 1.

As shown in FIG. 1, the cross joint has a cross-shaped spider 3 interposed between a pair of yokes 1 and 2. To be more specific, as shown in FIG. 2, a spider shaft 6 is rotatably fitted into a bearing hole 4 of the yoke 1 through a needle bearing 5. A seal member 7 is provided along an outer periphery of a lower portion of the spider shaft 6. The yoke may be manufactured by any one of sheet metal working, forging and casting and composed of any one of ferro-series and alumi-series materials.

Further, a pin 9 composed of a synthetic resin is inserted into an axial hole 8 formed in an axial core of the spider shaft 6. The needle bearing 5 is provided with a metallic cup 10 fitted in the bearing hole 4. A plurality of rolling members (rollers) 11 are arranged inwardly of this cup 10.

In the first embodiment, an outside diameter of a contact portion 6a of the spider shaft 6 is set larger than an outside diameter of a central portion 6b thereof, and a bottomed hole 12 is formed at a central portion of each end of the spider shaft 6.

Thus, the outside diameter of the contact portion 6a of the spider shaft 6 is set larger than that of the central portion 6b thereof, and hence the fitting between this contact portion 6a and the

needle bearing 5 can be set to have an interference (or a minute gap). Accordingly, even when vibrations are propagated from the wheels, noises emitted due to the interference between the spider shaft 6 and the
5 needle bearing 5 can be reliably prevented by keeping uniform the minute gap between the central portion 6b of the spider shaft 6 and the needle bearing 5.

On the other hand, since the contact portion 6a of the spider shaft 6 has the bottomed hole 12 at the
10 central portion of the end of the spider shaft 6, the contact portion 6a is formed in a comparatively thin ring shape. Hence, the contact portion 6a has a comparatively small rigidity in its radial direction and, even when the fitting between the contact
15 portion 6a and the needle bearing 5 is set to have the interference, causes neither a large contact surface pressure nor a problem in terms of durability. Further, similarly, when assembling the cross joint to the yoke 1, a load for inserting (press-fitting)
20 the needle bearing 5 is relatively small, and there is no real difficulty with the assembly process.

Moreover, there is no necessity of enhancing a dimensional accuracy of each component, and the contact portion of the spider shaft 6 is expanded in
25 its diameter and is formed merely with the bottomed hole 12. This configuration does not bring about a rise in the manufacturing cost.

Moreover, the contact portion 6a of the spider shaft 6 is formed in a comparatively thin ring shape. Therefore, if a large load is propagated, the contact portion 6a becomes flexural, however, the central
5 portion 6b of the spider shaft 6 receives a large proportion of the load. Hence, there does not arise any significant problem in terms of strength.

Note that an axial diameter of the spider shaft is approximately 10 mm, a depth of the bottomed hole
10 12 is 1.8 through 3.5 mm and preferably 2 through 3 mm, a radial thickness of the thin ring-shaped portion of the contact portion 6a is 0.6 to 1.2 mm, and a level difference (that is, a minute gap S in FIG. 2 between the central portion 6b and the rolling
15 member 11) is 0.004 to 0.020 mm. Note that the minute gap indicated by the symbol S is illustrated in exaggeration.

Further, a material of spider 3 is JIS chrome molybdenum steel material SCM420 or 421, or chrome
20 steel material SCr420 or 430. Moreover, a thermal treatment of the spider 3 is an overall carburization quenching treatment, and preferably the bottomed hole 12 is prevented from being carburized. Further, the outside diametric portion of the spider shaft 6 is
25 worked by grinding, and a chamfer portion of the side end surface is not ground. Moreover, the cross joint in the first embodiment is used mainly in an engine

room for a vehicle.

[Second Embodiment]

FIG. 3 is a sectional view showing a cross joint in a second embodiment of the present invention.

5 according to the second embodiment, the synthetic resin pin 9 is not provided, and therefore the bottomed hole 112 takes a conical shape, which leads to a less cost than in the first embodiment.

The cross joint in the second embodiment is,
10 however, limited to the use in the driving room. Further, the seal member 107 is composed of a nitrile rubber. Other configurations and operations are the same as those in the first embodiment.

[Third Embodiment]

15 FIG. 4 is a sectional view showing a cross joint in a third embodiment of the present invention. According to the third embodiment, the contact portion of the spider shaft is formed as a separate member. Namely, the spider shaft 206 is formed with
20 an axial hole 13, and a separate spacer 14 is fitted into this axial hole 13.

A protrusion 14a of this spacer 14 is press-fitted into the axial hole 13, and a thin ring-shaped portion 14b of the spacer 14 functions as the contact
25 portion 6a in the first and second embodiments does. According to the third embodiment, the grinding of the outside diametric portion of the spider is easier

than in the first and second embodiments. Other configurations and operations are the same as those in the first embodiment.

[Fourth Embodiment]

5 FIG. 5 is a sectional view showing a cross joint in a fourth embodiment of the present invention. The fourth embodiment has such a configuration that a bottomed hole is not provided in contrast with the first embodiment.

10 Therefore, the working of the spider shaft 306, 306a, 306b becomes easier than in the first embodiment. The contact surface pressure with the needle bearing 5 is, however, higher than in the first embodiment, and hence there is a necessity of
15 setting the interference with the needle bearing 5 smaller than in the first embodiment. Other configurations and operations are the same as those in the first embodiment.

[Fifth Embodiment]

20 FIG. 6 is a sectional view showing a cross joint in a fifth embodiment of the present invention. A configuration in the fifth embodiment is that, in contrast with the first embodiment, the spider shaft 406, 406a, 406b is not formed with an axial hole and
25 is therefore solid, and a bottom central portion 15 of the cup 410 of the needle bearing 405 is brought into contact with a side end surface of the spider

shaft 406.

Hence, the working of the spider shaft 406 is easier than in the first embodiment. The contact surface pressure with the needle bearing 405 is, however, higher than in the first embodiment, and hence there is a necessity of setting the interference with the needle bearing 405 smaller than in the first embodiment. Other configurations and operations are the same as those in the first embodiment.

[Sixth Embodiment]

FIG. 7 is a sectional view showing a cross joint in a sixth embodiment of the present invention. a configuration in the sixth embodiment is that an interference portion of the fitting between the needle bearing 5 and the contact portion 506a of the spider shaft 506 is set close to a proximal end of the spider shaft 506.

Hence, the working of the spider shaft 506 is easier than in the first embodiment. Other configurations and operations are the same as those in the first embodiment.

The contact portion 506a of the spider shaft 506 may be provided in an arbitrary position ranging extending from the front side end of the spider shaft 506 to its proximal end.

[Seventh Embodiment]

FIG. 8 is a sectional view (taken in a direction of the vertical axis of the center of the joint in FIG. 1) showing a cross joint in a seventh embodiment of the present invention. According to
5 the seventh embodiment, one (an upper side in FIG. 8) of two pieces of spider shafts 606 facing to each other is interference-fitted, while the other (a lower side in FIG. 8) is loose-fitted.

One interference-fitted spider shaft 606 (the
10 upper side in FIG. 8) has the contact (a large-diameter portion) 606a provided close to the proximal end thereof, and the distal end portion there is loose-fitted.

The other loose-fitted spider shaft 606 (the
15 lower side in FIG. 8) has no stepped portion and is formed in a straight shape.

A spider shaft 606 orthogonal to the above spider shaft 606 has the same configuration. Other configurations and operations are the same as those
20 in the first embodiment.

Note that the cost required in the seventh embodiment might be less than in the first through sixth embodiments, however, the noise preventive effect gets declined. Further, if four pieces of
25 spider shafts 606 having the interference-fitted contact portions (large-diameter portions) 606a are reduced down to one single spider shaft 606, a still

less cost can be expected, however, the noise preventive effect falls into a further decline.

[Eighth Embodiment]

FIG. 9 is a sectional view showing across joint
5 in an eighth embodiment of the present invention. A configuration in the eighth embodiment is that the interference-fitted contact portion (large-diameter portion) 706a is provided at the proximal end of the spider shaft 706, a piece 16 is provided between the
10 bottom surface of the cup 710 and the side end surface of the spider shaft 706. Other configurations and operations are the same as those in the first embodiment.

Note that a length (L) of the interference-
15 fitted portion is set equal to or larger than 1.5 mm, preferably 2 mm on the basis of calculations and results of a multiplicity of tests performed. With this dimensional requirement attained, the durability can be ensured. Further, these numerical values are
20 the same with the fourth through seventh embodiments.

Moreover, an outside diameter of the rolling member 11 is 1.4 to 2.3 mm, and the number of the rolling members 11 is 16 to 25. An outside diameter of the cup 10 is 15 to 16 mm. These numerical values
25 are the same with the first through eighth embodiments.

Further, an extreme-pressure additive is added

to grease (lubricating oil) filling an internal space 705a of the needle bearing 705. This addition enables a bending torque can be further decreased. The specific extreme-pressure additives may be
5 exemplified as follows:

- Disulfide molybdenum
- Sulfur-series (S) extreme-pressure additives
- Sulfur-phosphorus-series (S-P) extreme-pressure additives
- 10 • Zinc-sulfur-phosphorus-series (Zn-S-P) extreme-pressure additives.

It is to be noted that this grease may be used in other embodiments.

As discussed above, according to the first
15 through eighth embodiments of the present invention, the contact portion of the spider shaft sets its outside diameter larger than the outside diameter of the central portion thereof, and hence the fitting between this contact portion and the rolling bearing
20 can be set to have the interference (or the minute gap). Accordingly, even when the vibrations are propagated, the noises emitted due to the interference therebetween can be reliably prevented by keeping uniform the minute gap between the central
25 portion of the spider shaft and the rolling bearing.

On the other hand, the contact portion of the spider shaft has the bottomed hole formed in the

axial core side end surface thereof and therefore takes on a comparatively thin ring shape.

Accordingly, the contact portion is relatively small in its rigidity in the radial direction thereof and, even when the fitting between the contact portion and the rolling bearing is set to have the interference (or the minute gap), causes neither a large contact surface pressure nor a problem in terms of durability. Further, similarly, when assembling the cross joint to the yoke, the load for inserting (press-fitting) the rolling bearing (the needle bearing) is relatively small, and there is no real difficulty with the assembly process.

Moreover, there is no necessity of enhancing or improving the dimensional accuracy of each component, the contact portion of the spider shaft is expanded in its diameter and is formed merely with the bottomed hole. This configuration does not bring about a rise in the manufacturing cost.

Moreover, the contact portion of the spider shaft is, as described above, formed in a comparatively thin ring shape. Therefore, if a large load is propagated, the contact portion becomes flexural, however, the central portion of the spider shaft receives the large proportion of the load. Hence, there does not arise the problem in terms of the strength.

[Ninth Embodiment]

FIG. 10A is a side view including a partially cut-off section, showing a cross joint in a ninth embodiment of the present invention. FIG. 10B is a sectional view of the cross joint illustrated in FIG. 10A.

As shown in FIG. 10A, the cross joint has the cross-shaped spider 3 is interposed between the pair of yokes 1 and 2. To be more specific, as shown in FIG. 10B, the spider shaft 806 is fitted into the bearing hole 4 of the yoke 1 through the needle bearing 805 in a manner such that it is capable of oscillating movement. The seal member 7 is provided along the outer periphery of the lower portion of the spider shaft 806. The yoke may be manufactured by any one of sheet metal working, forging and casting and composed of any one of ferro-series and alumi-series materials in the ninth embodiment and other embodiments which follow.

The pin 9 composed of the synthetic resin is inserted into the axial hole 8 formed in the axial core of the spider shaft 806. The needle bearing 805 is provided with the metallic bearing cup 810 fitted in the bearing hole 4. The plurality of rolling members (rollers) 811 are arranged inwardly of this cup 810.

In the case of taking the conventional gap-

fitting between the spider shaft 806 and the needle bearing 805, noises occur during the traveling of the vehicle.

5 The ninth embodiment takes the interference-fitting between the needle bearing 805 and the spider shaft 806, and hence the emission of the noises due to the interference between the spider shaft 806 and the needle bearing 805 can be surely prevented without bringing about the rise in the manufacturing
10 cost. The interference is set to 0 through 0.035 mm and preferably 0.002 to 0.025 mm.

 The needle bearing 805 is classified as an overall roller type, an outside diameter of the cup 810 is approximately 15 to 16 mm, an inscribed
15 circle diameter of the roller 811 is on the order of 10 mm, an outside diameter of the roller 811 is 1.4 through 2.3 mm, and the number of rollers 811 is 16 to 25.

 When a steering shaft of the vehicle is steered,
20 a steering wheel (unillustrated) is rotated, with the result that the spider shaft 806 is oscillated. An angle of this oscillation is determined by a joint fitting angle in the vehicle and is on the order of \pm 30 degrees in the case of an ordinary car.

25 The roller 811 smoothly rotates owing to the oscillations of the spider shaft 806, however, the axial core of the roller 811 is not parallel but

inclined to the axis of the spider shaft 806 in many cases, and the roller 811, with its rotation, moves in the axial direction within the cup 810.

5 The inclination of the roller 811 occurs in the case of the interference fitting as a result of testing and is substantially fixed depending on a gap in the peripheral direction between the rollers 811. In the ninth embodiment, this gap in the peripheral gap is 0.05 through 0.21 mm.

10 In the case of a conventional steering joint, when the oscillations are caused, the rollers 811 would ordinarily move in the axial direction and come into contact with either walls 810a, 810b of the cup 810, and sliding would occur between the rollers 811
15 and the walls 810a, 810b of the cup 810. Further, sliding in the axial direction would occur between the rollers 811 and the spider shaft 806, whereby the bending torque would increase (resistance increases when oscillated). Especially when the fitting gap is
20 negative (interference), this tendency becomes conspicuous.

 According to the ninth embodiment, a gap (M-N) in the roller axial direction within the cup 810 is set to 0.6 mm or larger. This gap (M-N) is
25 determined from result of a multiplicity of tests and is preferably 0.9 mm or greater. Namely, the roller within the bearing cup of the needle bearing is so

structured as to be movable 0.6 mm or larger in the axial direction. As a result, when the joint is bent, the rollers 811 rotate and move in the axial direction within the cup 810 with the oscillations of the spider shaft 806. Even in such a case, the walls 810a, 810b of the cup 810 have neither the contact of the rollers 811 nor sliding with respect to the rollers. Accordingly, a smooth feeling of the steering can be obtained by reducing the bending torque of the steering shaft.

There might be a case where the rollers 811 have already been brought into contact with the walls 810a, 810b of the cup 810 after the assembly, or a case where the rollers reside in the vicinity of the walls 810a, 810b. In this case, with the joint bent, the rollers 811 are once brought into contact with the walls 810a, 810b, and the bending torque increases. When the joint gets resilient from the bending state, however, the rollers 811 become separate from the walls 810a, 810b and move in the opposite direction (i.e., in the central direction) owing to inclinations of the rollers 811. Next, even when bent in the same direction as done for the first time, a bending angle thereof is kept till the rollers 811 come into contact with the walls 810a, 810b of the cup 810, and therefore the bending torque does not increase.

[Tenth Embodiment]

FIG. 11 is a sectional view showing a cross joint in a tenth embodiment of the present invention. The tenth embodiment does not involve the use of the synthetic resin pin. Other configurations and operations are the same as those in the ninth embodiment.

[Eleventh Embodiment]

FIG. 12 is a sectional view showing a cross joint in an eleventh embodiment of the present invention. According to the eleventh embodiment, a bottom wall of the cup 910, 910a, 910b is formed with a protrusion 910c coming into contact with the side end surface of the spider shaft 906. Further, the side end surface of the roller 911 in the bearing is spherical. Other configurations and operations are the same as those in the ninth embodiment.

[Twelfth Embodiment]

FIG. 13A and 13B are sectional views each showing a cross joint in a twelfth embodiment of the present invention. According to the twelfth embodiment, the spider shaft 1006 has a stepped portion, and a length of the contact with the roller 11 is set short. Namely, an end-side major diameter of the spider shaft 1006 is set small in FIG. 13A, and a proximal-side major diameter of the spider shaft 1106 is set small in FIG. 13B. With these

settings, when the bearing is assembled, a press-fitting load thereof becomes small because of the short contact length with the spider shaft, thereby facilitating the assembly. Other configurations and operations are the same as those in the ninth embodiment.

[Thirteenth Embodiment]

FIG. 14A is a sectional view showing a cross joint in a thirteenth embodiment of the present invention. In the thirteenth embodiment, a piece 20 composed of the synthetic resin is used as a substitute for the synthetic resin pin 9. That is, the piece 20 is provided between the bottom surface of the cup 110 and the side end surface of the spider shaft 106. Other configurations and operations are the same as those in the ninth embodiment.

Further, the extreme-pressure additive is added to the grease (lubricating oil) filling the internal space 105a of the needle bearing 105. This addition enables the bending torque can be further decreased. The specific extreme-pressure additives may be exemplified as follows:

- Disulfide molybdenum
- Sulfur-series (S) extreme-pressure additives
- Sulfur-phosphorus-series (S-P) extreme-pressure additives
- Zinc-sulfur-phosphorus-series (Zn-S-P) extreme-

pressure additives.

It is to be noted that this grease may be used in other embodiments. Moreover, the length (L) of the interference-fitted portion is set equal to or
5 larger than 1.5 mm, preferably 2 mm on the basis of calculations and results of a multiplicity of tests performed. With this dimensional requirement attained, the durability can be ensured.

[Fourteenth Embodiment]

10 FIG. 14B is a sectional view showing a cross joint in a fourteenth embodiment of the present invention. In accordance with the fourteenth embodiment, the needle bearing 1205 is provided with a cage 13. In this case, the following relationship
15 is established.

$$M - N - S1 - S2 \geq 0.6 \text{ mm}$$

According to the fourteenth embodiment, the needle bearing 1205 is provided with the cage 13, and consequently the cost is higher than in other
20 embodiments that do not involve the use of the cage. The rollers 1211 are, however, inclined without no relation with each other and therefore have a less possibility of their being tilted in one direction as in the overall roller type. Hence, a force by which
25 the spider shaft 1206 moves in the axial direction is small, and an anti-abrasion of the contact portion between the protrusion 1210c on the bottom wall of

the cup 1210 and the side end surface of the spider shaft 1206, is enhanced.

5 The ninth through fourteenth embodiments involve the use of the shell type needle bearing and may also involve the use of a solid type needle bearing. Further, two shafts facing to each other may take the shell type needle bearing, and the two shafts substantially orthogonal thereto may take the solid type needle bearing.